

Individually-unique Spot Patterns of Young-of-the-Year Giant Sea Bass (*Stereolepis gigas*) in Captive-raised Fish

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Abstract.—Young-of-the-year Giant Sea Bass (*Stereolepis gigas*) (hereafter YOY GSB) spend the first several months after planktonic settlement within recreational dive limits. After settlement, YOY GSB morph through pigmentation phases where patterns of black spots unique to individual fish appear against the fish's lighter background. In order to prove that underwater photographs of spot patterns could be used to individually identify and possibly track YOY GSB in the field, several YOY GSB were captured and raised at public aquaria. Both sides of each fish were planned to be photographed monthly for a year from the capture date. The black spots of YOY GSB are so few and distinct that computer programs developed to discern individuals of species with complicated spot patterns were not necessary for re-identification of individuals. Three fish that were followed for twelve months in captivity could be individually identified by comparing photographs of their spot patterns by eye. A fourth fish that survived for six months could also be individually distinguished through photographs. This is the first published study to follow the development of YOY GSB spot patterns. Underwater photo-identification techniques could be used to re-identify individuals from several months to at least a year after planktonic settlement. That no capture-recapture studies have been conducted on YOY GSB to date hinders the basic understanding of species ecology and population dynamics. This study opens the door to the use of underwater photography as a passive mark and recapture method for studying YOY GSB along soft-bottomed nursery beaches where they can be found for the first few months after settlement.

The adult Giant Sea Bass (*Stereolepis gigas*) (GSB) is the largest teleost inhabiting California's nearshore habitats, attaining a length of about 2.3 m (7 ft) and a maximum weight of approximately 256 kg (564 lbs) (Baldwin and Keiser 2008). They range from Humboldt Bay, California to Oaxaca, Mexico, including the Gulf of California (Kells, Rocha, and Allen 2016). Adults occur over rocky and sandy bottoms and kelp beds from near shore to approximately 46 m (150 ft) of water (Kells et al. 2016). After their peak commercial catch in 1932 at just over 114,000 kg (12.6 tons), the population quickly crashed and their numbers have remained below historic levels ever since (Pondella and Allen 2008). GSB are now prohibited from intentional take in California by sport and commercial fishermen; however, commercial gill and trammel net fishermen can keep and sell one fish per trip if caught while targeting other species. GSB incidentally caught in other gear, such as squid purse seines, may not be kept.

During the non-spawning season, the background pigmentation of mature GSB is typically gray to dark brown dorsally, fading to a light copper-brown ventrally. Males show a pattern of black spots and white patches throughout their lives. Females exhibit a pattern of black spots and white patches for most of the year, but become dark brown during spawning episodes, totally obscuring the characteristic spots (Hovey 2001).

Young-of-the-year is a term describing a fish less than a year old. YOY GSB occupy habitat between 2 m to at least 38 m (7-125 ft) in depth for the first few months after planktonic

settlement. During this period, YOY GSB occupy wide expanses of open sand and mud-bottomed habitat away from rocks, jetties, piers, debris, and other hard structures that often hold predators large enough to eat them at this vulnerable size. YOY GSB pass through several background pigmentation phases and morphological changes during the first few months after settlement, and these transitions help them to appear cryptic while they are hiding to avoid predators (Couffer and Benseman 2015).

When less than 20 mm (0.8 in) in length (all lengths given are total lengths) YOY GSB appear black with several small white patches around the face and sides (Fig. 1). Black-phase YOY GSB have large black dorsal and pelvic fins, and translucent pectoral, anal, and caudal fins. From about 20 mm to about 40 mm (1.6 in), their background pigmentation lightens from black through a brown phase (Fig. 2) into an orange fish (Fig. 3). Dorsal fin pigmentation mirrors the background pigmentation seen on the sides. The large pelvic fins remain black. As the background pigmentation changes from black to brown, the white patches remain, and black spots become visible (Couffer and Benseman 2015).

During the black phase, black spots do not appear to exist on the sides, invisible against the black background. This was discovered when the background pigmentation of a live-captured black-phase YOY GSB that was bottled and placed in a lightless pouch turned nearly white within the space of a few minutes; it returned to black several seconds after re-exposure to sunlight. No black spots were visible during the pigment change, and spots did not appear as the fish returned to black. Unstressed black-phase fish observed during focused surveys at night were initially found black, so it appears that the change in shade within the bottle was a stress-related change, and not a nocturnal change.

In the orange phase, the black spots are distinct against the background. The shapes of these spots may be round, dumbbell-shaped, or square. The sides and both hard and soft dorsal fins can lighten significantly when they become agitated (Fig. 5); however, regardless of the stage of agitation of the fish, all of their black spots remain prominent. Lightening of the background pigmentation enhances the visibility of the black spots, but can obscure some white patches.

By 200 mm (7.9 in), the orange background has become an irregular pattern of bronze and silvery splotches (Fig. 4). Bronze and black pigment has filled the previously-translucent dorsal and anal fins, as well as half of the caudal fin. The pectoral fins are still translucent, and the pelvic fins remain black. The black spots on the sides remain visible, but black spots have also appeared on the dorsal fin. Based on my field observations of 118 individuals during 186 hours of focused surveys to date, YOY GSB of this size have already left the shallow, soft-bottomed nursery areas, and are not easily accessible for study.

Occasionally, YOY GSB in the field displayed damage to their sides that obscured black spots. It is unknown whether or not the black spots that had developed prior to the damage would reappear in the same places on the sides after complete recovery. A full-length caudal fin tear of one captive fish healed so completely in one month that no damage was discernable in photographs. Moderate scrapes and fin tears may be useful for re-identification for a few weeks, but perhaps not over a year's time. However, significant damage might mark a fish for life.

That no capture-recapture studies have been conducted on YOY GSB to date hinders the basic understanding of species ecology and population dynamics of GSB. This is the first published study to follow the development of young-of-the-year GSB spot patterns. Underwater photo-identification techniques could be used as a passive mark and recapture method for studying young-of-the-year Giant Sea Bass along soft-bottomed nursery beaches where they can be found for the first few months after settlement.

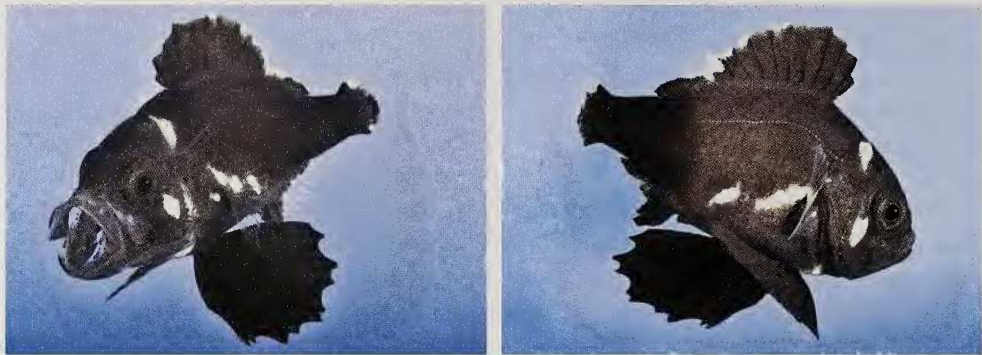


Fig. 1. 18 mm Black-phase GSB.



Fig. 2. 30 mm and 37 mm Brown-phase GSB.

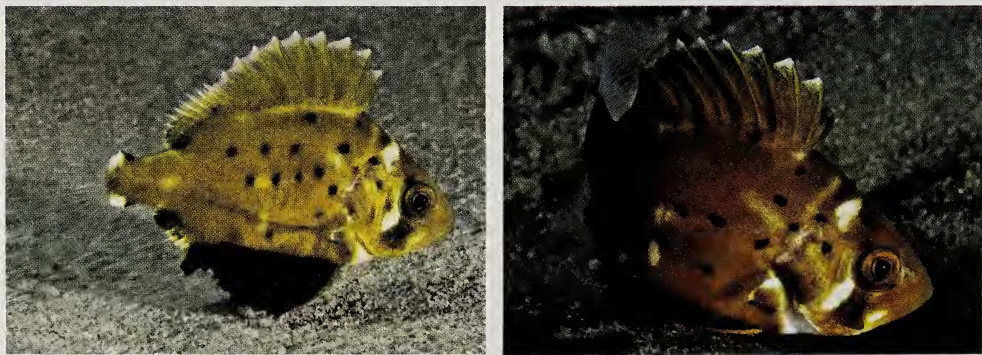


Fig. 3. 40 mm and 45 mm Orange-phase GSB.

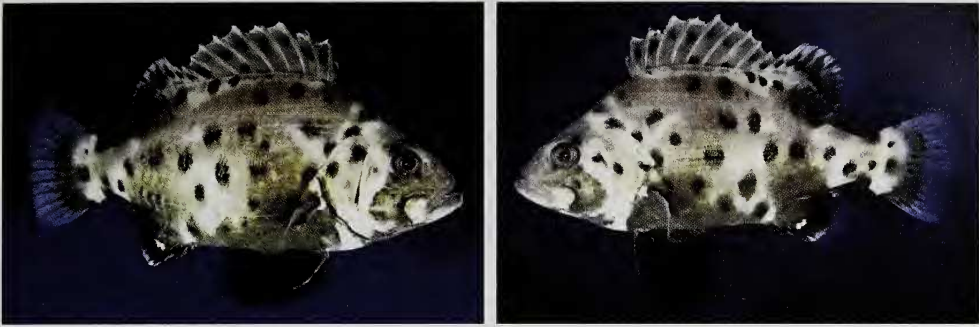


Fig. 4. 194 mm Yearling GSB.



Fig. 5. 98 mm GSB. Background pigment lightens from agitation (shots taken 8 minutes apart).

Materials and Methods

To determine whether or not photo re-identification of individual YOY GSB in the field was possible, I established a baseline by photographically following the changes in spot patterns of captive YOY GSB that were isolated from one another. The main goal of the project was to determine whether or not the black spot pattern of an individual YOY GSB remained similar enough over the course of a year that it might be re-identified using underwater photos taken by recreational divers and focused surveyors in the field. Since all field photos taken by future divers would represent fish of different ages after settlement, it was not necessary that all fish used in the current study be of the same age, size, or pigmentation phase. All YOY GSB followed in this study were captured at different ages after planktonic settlement.

Because YOY GSB husbandry had historically been difficult (Shane et al. 1996), it was possible that not all of the fish being followed for this study would survive a full year in captivity. Collecting photo pairs each month was designed to ensure that if a fish died, any monthly spot pattern changes until death would be documented. Once a month, photos were planned to be taken with the right and left sides of the fish perpendicular to the lens. This would allow a month-to-month comparison of any change in the spot patterns of individual fish, as well as comparisons in patterns between different captive fish.

In 2014, a brown-phase YOY GSB was received by Cabrillo Marine Aquarium in Los Angeles County; I photographed the fish monthly until it expired in 2015. In 2016, my California Department of Fish and Wildlife scientific collecting permit was augmented to include the capture of several YOY GSB. I made verbal agreements with several local aquaria to provide them with fish to raise for the spot pattern study. In return, the aquaria could exhibit the GSB for

educational purposes, and could conduct additional studies. I partnered with the Ocean Institute in Dana Point, Orange County, and the Santa Monica Pier Aquarium in Santa Monica, Los Angeles County. As Monterey Bay Aquarium in Monterey County, and Aquarium of the Bay in San Francisco County showed great interest in acquiring YOY GSB for study and educational display, they were also provided with fish, under the condition that they would collect monthly pairs of photos, total lengths, and weights for my spot pattern study.

Many different factors will alter the color of photographs of fish taken in the field and in captivity. In the field, fish colors captured by different underwater photographers are even more difficult to standardize than in aquariums. In addition, all YOY GSB are able to alter their background shade within a few seconds. For these reasons, the specific colors of fish followed in this study were not important. In order to avoid the distraction of differently-pigmented fish and photographic backgrounds, all spot pattern comparison color photos were changed to black and white so that viewers could more easily focus on the spot patterns.

Photographs were taken with digital single lens reflex cameras. A Canon 60 mm lens was used on a cropped-sensor camera body to enhance the depth of field when photographing small YOY GSB. Initially, the two flash heads of a Canon Macro Twin Lite (MT 24 EX) were positioned on either side of the lens using the original equipment mount. As fish grew, the flash heads were spread away from the lens on fabricated arms. A Sigma 35 mm lens was used on a full-sized sensor camera body for larger fish. A rubber lens hood was pressed against the tank to block stray flash reflections from hitting the outside of the glass and entering the lens. Photo backgrounds were placed inside tanks to prevent reflections off the glass aquarium backs. Aquariums purchased for the project were only used for GSB photography to prevent scratches. In order to keep GSB from reacting to their moving reflections off tank bottom glass, tank bottoms were covered with substrate or patterned foam core. The image processing program Adobe Photoshop was used to crop, straighten, and sharpen photos, remove suspended particles, and to alter contrast in order to enhance spot patterns.

The black spots of YOY GSB are so few and distinct that computer programs developed to discern individuals of species with complicated spot patterns were not used for re-identification of individuals. However, a trained eye in the field is not enough to provide proof of re-identification. Clear photographs of the fish's sides provide visual proof of re-identification.

Discussion

I collected 12 pairs of monthly photos of the Santa Monica Pier Aquarium and Ocean Institute fish for one year. This resulted in a series of 24 photos of each fish showing gradual changes in pigment and form as they matured over the course of a year. For brevity, I present these photo pairs at three month intervals for the Santa Monica Pier Aquarium fish (Figs. 6-10), and the Ocean Institute fish (Figs. 11-15). I shot monthly pairs of photos of the Cabrillo Aquarium fish for 6 months until the fish expired (Figs. 16-18); these photo pairs are also presented at three month intervals. The intent of providing YOY GSB to Monterey Bay Aquarium and Aquarium of the Bay was that monthly pairs of side photos would be taken of each fish at the time when morphometric measurements were taken for another study. Unfortunately, two fish died without any monthly side photos being taken, leaving only my initial photos taken the day of capture. I took initial photos of both sides of one YOY GSB before it was transported to Aquarium of the Bay, but the fish died 81 days later without any additional photos of the living fish having been taken. My color image of the left side of the Aquarium of the Bay fish taken the day of capture is shown on the right side of Fig. 2. One of the two Monterey Bay Aquarium fish persisted, and exactly one year after the initial side photos were taken (Fig. 19) I traveled to Monterey to take

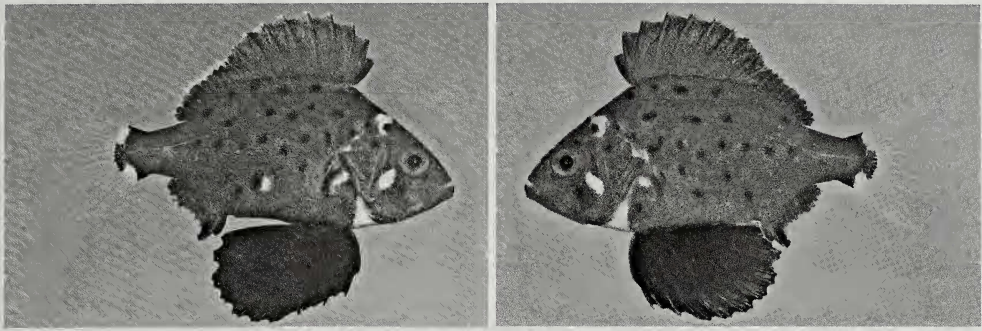


Fig. 6. Capture Date – 27 November 2015 (37 mm).

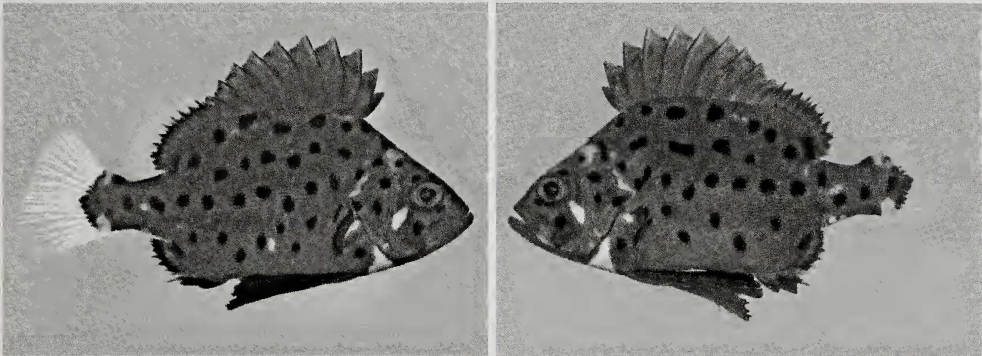


Fig. 7. Three Months from Capture - 16 February 2016 (73 mm).

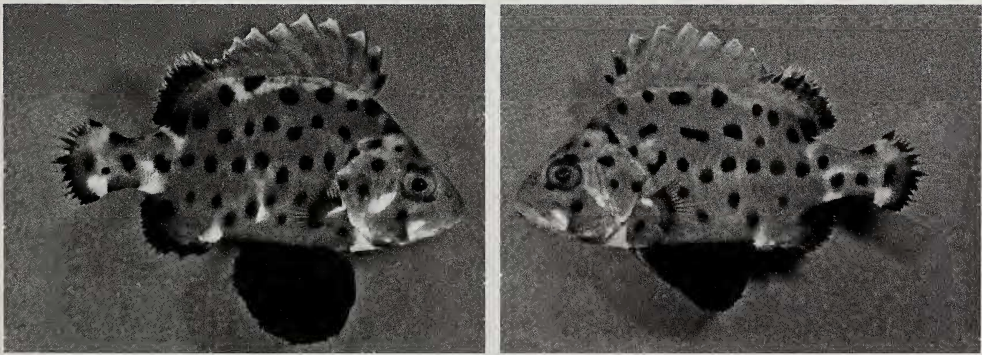


Fig. 8. Six Months from Capture - 14 May 2016 (120 mm).

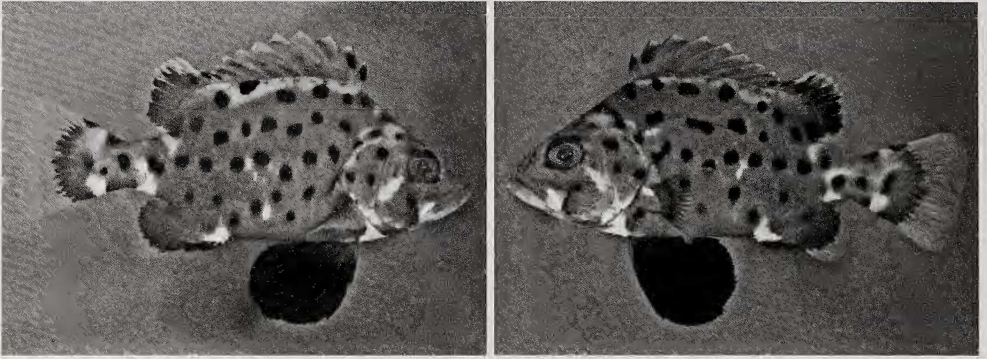


Fig. 9. Nine Months from Capture – 19 August 2016 (146 mm).

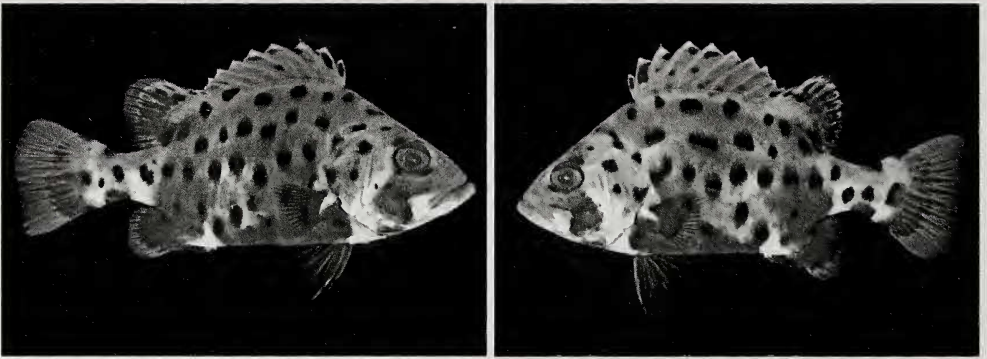


Fig. 10. One Year from Capture - 28 November 2016 (178 mm).

the final photos of this fish (Fig. 20). Although no monthly photos were taken of this fish, the first and final pairs of photos provided evidence for the fish to be included in the study.

Conclusions

The pattern of black spots that develops on the body of a YOY GSB during the transition from the black phase to the brown phase is unique to each individual. Nearly all of the black spots on the sides of the fish become visible during the transition from the black phase to the brown phase. On some fish, a few spots that appear very faint in the brown phase enlarge and darken in the early orange phase. Black spots that develop on the dorsal fin late in the year appear too late in a YOY GSB's development to be used for individual identification during the time when YOY GSB are available to divers within their nursery areas. After all of the black spots on the body become fully visible, their general shapes and relative positions change little across a year's time. This was clearly evident by simple observation of the photographs and did not require sophisticated pattern recognition software to re-identify individuals or to differentiate between individuals.

The black spots of YOY GSB are so few and distinct that computer programs developed to discern individuals of species with complicated spot patterns are not necessary for re-identification of individuals. Each of the three captive-raised YOY GSB that survived for twelve months could be individually identified using photographs of their spot patterns up to a year after collection. Pairs of photos of the Santa Monica Pier Aquarium and Ocean Institute fish taken three months

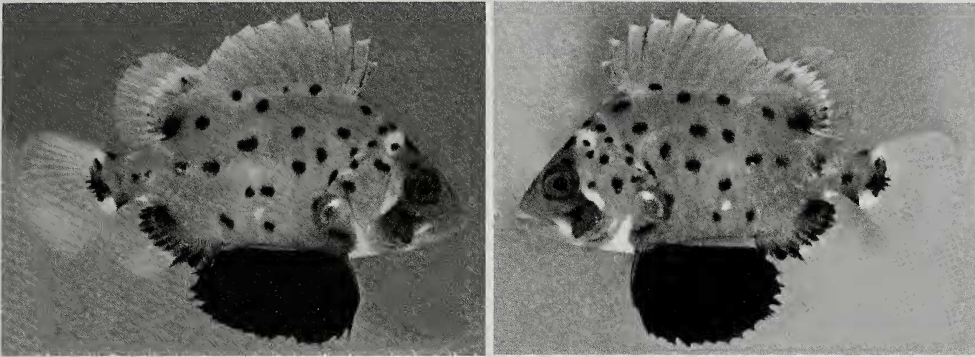


Fig. 11. Capture Date - 19 August 2015 (48 mm).

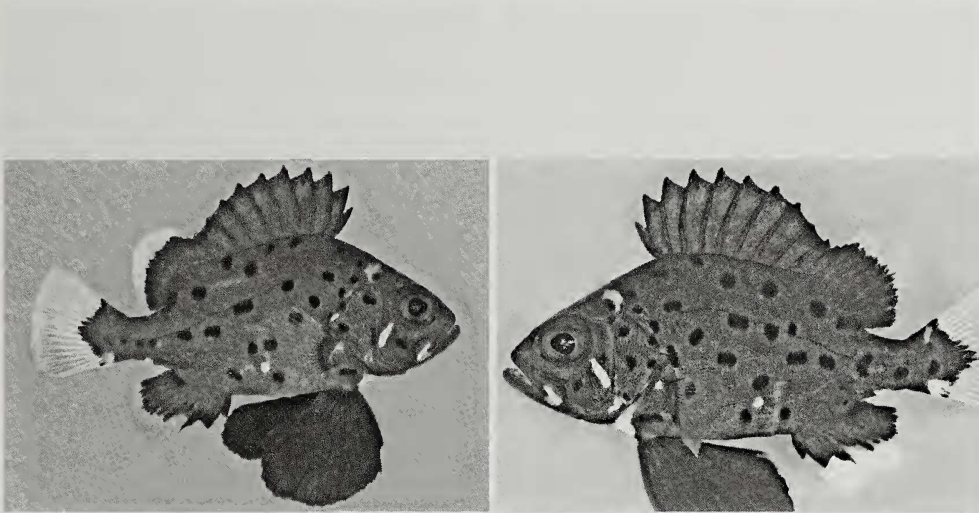


Fig. 12. Three Months from Capture - 17 Nov. 2015 (62 mm on 23 Nov. 2015).

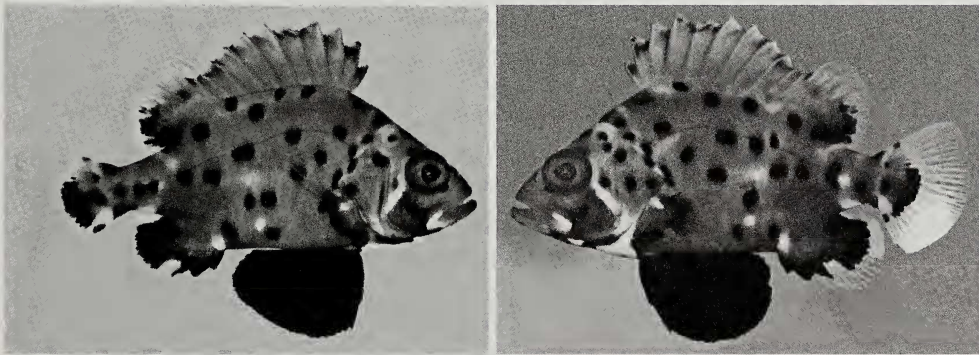


Fig. 13. Six Months from Capture - 18 Feb. 2016 (65 mm on 16 Feb. 2016).

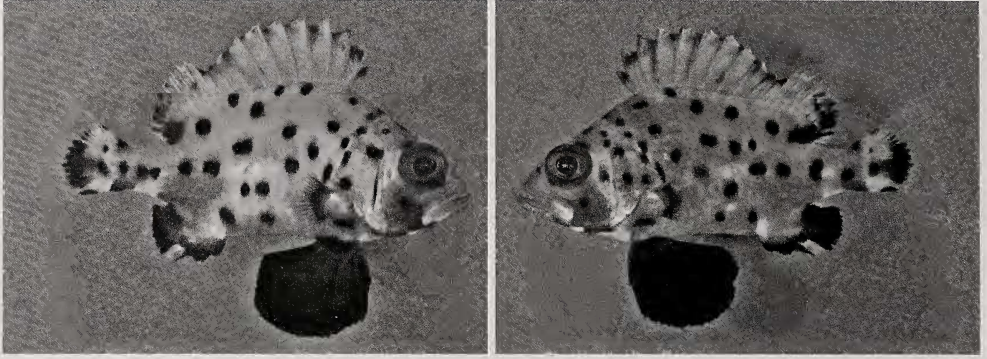


Fig. 14. Nine Months from Capture - 15 May 2016 (90 mm on 18 May 2016).

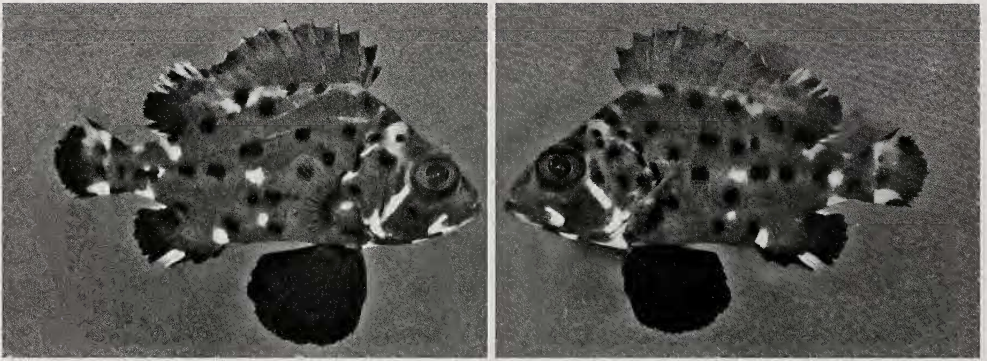


Fig. 15. One Year from Capture - 19 August 2016 (98 mm on 21 August 2016).

apart show a progression of change in spot size, but little change in relative spot positions. Pairs of side photos taken 365 days apart could be compared by eye to identify individuals by their spot patterns. While no intermediate photos were taken of the surviving Monterey Bay Aquarium fish, the initial and final photos, taken 365 days apart, showed that this fish could be re-identified by eye a year later by its spot pattern. The black spot pattern of the Cabrillo Aquarium fish that expired after six months showed little change, and a simple visual comparison of the initial and final photos shows that this fish remained identifiable during its change from brown to orange.

Regularly using the white patches of a black-phase fish to re-identify individuals may be problematic due to the few number of white patches that they present, as well as the difficulty of taking clear side photos of a wild fish that is between 10 and 20 mm in length. However, two photographers diving independently and without knowledge of the other's presence in the area each photographed a black-phase YOY GSB at La Jolla Shores on the same morning. I was present when the first photos were taken, and I measured the fish at 14 mm. That night, I was sent a second set of photos taken by another diver who photographed a fish later in the morning, and identified the second photos as being of the same individual GSB. Although the white patches of black-phase YOY GSB vary in number, size, and placement, it is doubtful that these could regularly be used to re-identify individual black-phase fish; photographic re-identification of individuals is more easily undertaken once the fish turns brown.

This is the first published study following the development of young-of-the-year Giant Sea Bass spot patterns. Underwater photo-identification techniques could be used to re-identify

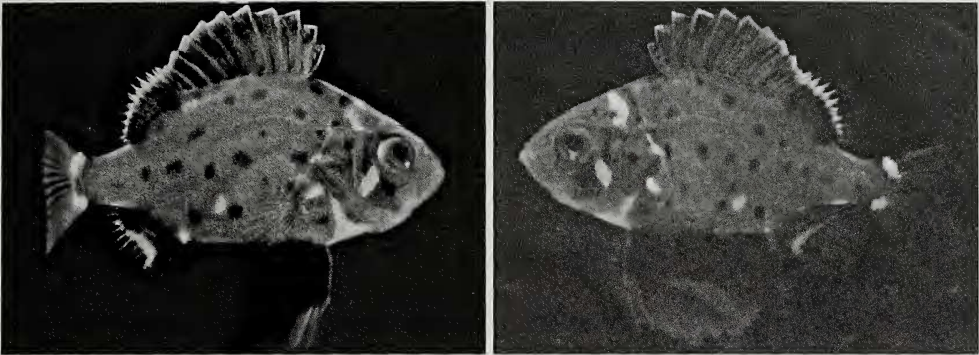


Fig. 16. Initial Photographs – 13 December 2014 (no measurements provided).

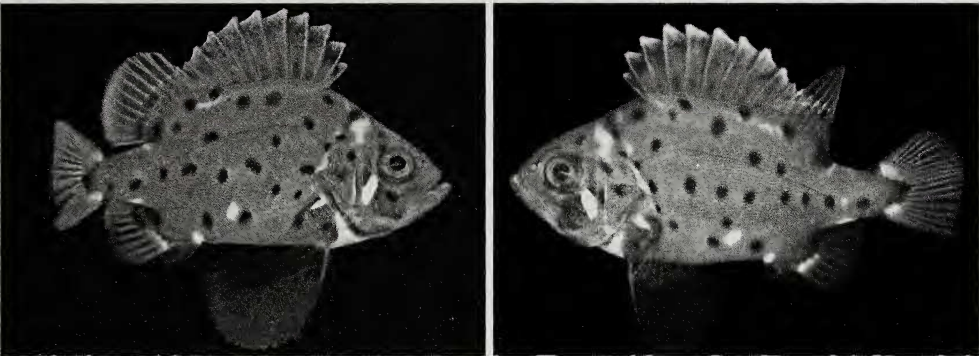


Fig. 17. Two and One Half Months from Capture - 1 March 2015 (no measurements provided).

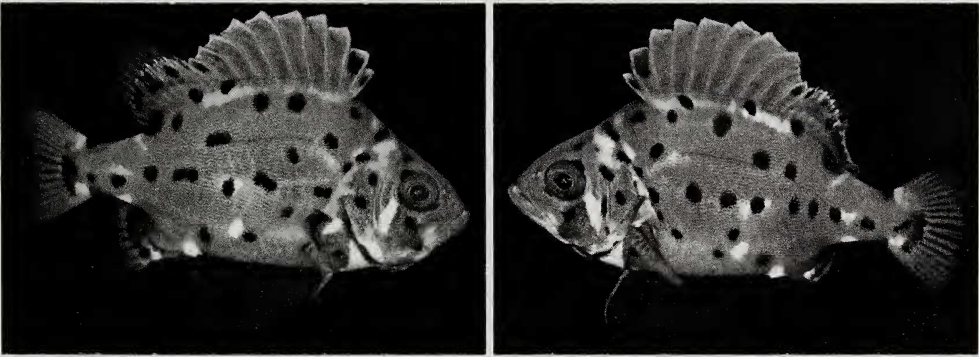


Fig. 18. Six Months from Capture - 17 June 2015 (no measurements provided).

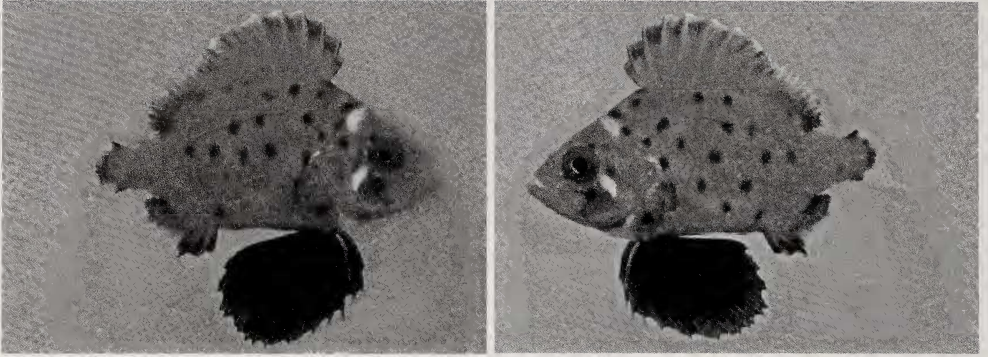


Fig. 19. Initial photo pair by Randy Wilder on 3 September 2015 (48 mm on 11 September 2015).

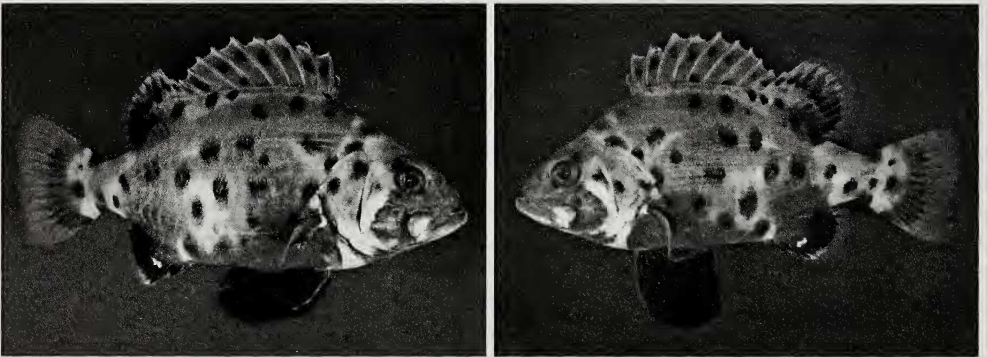


Fig. 20. One Year from Capture (194 mm on 3 September 2016).

individuals from several months to at least a year after planktonic settlement. This study opens the door to the use of underwater photography as a passive mark and recapture method for studying young-of-the-year Giant Sea Bass along soft-bottomed nursery beaches where they can be found for the first few months after settlement.

The few GSB nursery areas that have been located to date lie outside of all of Southern California's Marine Protected Areas, but within one state Marine Conservation Area, where fishing and beach sand replenishment activities are allowed. Details regarding the occupation of these areas by YOY GSB are expected to be published in a Masters thesis by Stephanie A. Benseman of California State University at Northridge. Direct and indirect impacts to these beaches and soft, shallow bottoms immediately offshore such as sedimentation from beach sand replenishment activities during the period when they are occupied by YOY GSB could impact these fish at a very sensitive stage of their development. This proof that individual YOY GSB can be re-identified using photographs of their spot patterns could influence any future protocols or methods developed for YOY GSB presence or absence and preconstruction surveys as well as biological monitoring for construction and maintenance of near-shore structures and beach sand replenishment projects undertaken within currently-known and potentially-occupied YOY GSB habitat.

Acknowledgements

I would like to thank the husbandry managers and staff of the aquaria who invested their time, expertise, resources, and care to raise YOY GSB for this project, and who assisted me with the logistics of tank photography. The surviving fish are available to provide data for other projects. These professionals include Jose Bacallao, Tracey Akino Higa, and Lazaro D. Serrano of Santa Monica Pier Aquarium; Julianne E. Steers, Jessica Brasher, and Kelsey Remmes of Ocean Institute; Kiersten Darrow and the husbandry staff of Cabrillo Marine Aquarium; Kevin O. Lewand, photographer Randy Wilder, and the husbandry staff of Monterey Bay Aquarium. I also thank Stephanie A. Benseman for training me to locate YOY GSB while conducting focused surveys for her Masters thesis at California State University, Northridge. Thanks also to Mark A. Pavelka and Michael W. Mitchell of the United States Fish and Wildlife Service, Larry G. Allen of California State University, Northridge, and several anonymous reviewers for providing valuable editing suggestions on manuscript drafts.

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